BRIEF

GEODETIC TARGET ERROR FOR THE ICBM IN RELATING LAUNCH AND TARGET POINTS ON DIFFERENT CONTINENTS

A. Origin of Problem

1. Continental systems of geodetic control end abruptly at coast lines.

2. Gaps in control over ocean areas create uncertainty in positioning of the continents.

3. The large geodetic sets of the world are based upon different datums.*

4. The US uses the North American Datum, adopted 1927; the USSR uses the Pulkovo 1942 Datum, adopted in 1946.

5. Datum differences give rise to errors in computing distances and directions between widely separated launch and target points.

B. Major Sources of Geodetic Uncertainty

1. Size of earth -- differences in values of the semi-major axis used for different ellipsoids.

2. Shape of earth -- different values used for polar flattening.

3. Orientation of ellipsoids -- ellipsoid axes do not coincide with earth's axis of rotation.

4. Errors due to deflections of the vertical -- result from angular differences between observations that are vertical to the geoid and computed as perpendicular to a displaced ellipsoid.

* See the Annex for explanation of the basic elements of the geodetic problem..

5. Map error -- determined by scale of available maps. Scale error negligible if maps are at scale 1:100,000 or larger but significant, particularly for locating Soviet ICBM launch sites, in areas for which best available maps are at scales of 1:1,000,000 or smaller.

6. Influence of gravity anomalies upon missile during early stages of flight.

C. Estimate of Geodetic Target Error: 5,500 Nautical Mile Range

	US Against USSR	USSR Against US
1. Error due to uncertainties in size, shape of ellipsoid, and target uncertainty	1,000 feet to 1 mile	1,000 to 2,000 feet
US against USSR:		
a. 1,000 feet applicable against pre-selected targets		
b. 1 n. mile applicable against Soviet launch sites with locations still to be ascertained		
2. Map error, varies with scale of available maps	200 to 2,000 feet	100 to 500 feet
3. Gravity error; lower value more probable	500 to 2,500 feet	500 to 2,000 feet
4. Estimated Over-All Geodetic Error		
Average instance	0.3 to 0.6 n. mile	
a. For 90 percent of European USSR targets	Within 1,000 feet	
b. For remainder of USSR		
50 percent certainty	2,000 feet to 1 n. mile	
90 percent certainty	4,000 feet to 2 n. mile	

D. US Moves to Improve Situation

1. Planned or current scientific programs to reduce geodetic error:

a. Defense World Geodetic System now determined but requires much refinement incorporating additional gravity data on land and at sea. Program hampered by gaps in gravity data over oceans and Soviet policy of withholding data on the USSR.

b. IGY lunar photography program; results expected in 1 to 2 years.

c. MIRAN (high-precision Shoran) for intercontinental ties. Results reduced uncertainty of connections between Europe and North America to about 246 feet; uncertainty still exists because of weaknesses in Canadian geodetic positions established by Shoran methods.

d. World gravity survey; still under consideration for oceanic survey. Surface-ship and airborne instrumentation now being tested; will reduce cost and speed up completion of survey.

e. Earth satellite observations and orbit analysis, results expected in next decade.

f. High-altitude rocket flashes for determining three-dimensional coordinates between continents giving positions free of deflection-of-the vertical errors; programs now in planning.

g. Reconnaissance satellite photography may within 5 years yield most direct and accurate checks on intercontinental positions and (hopefully) provide geodetic positions in the USSR for which data are now available.

2. Collection of large-scale maps and geodetic data (required to provide precise geographic reference points):

a. Soviet maps (1:100,000; 1:50,000; 1:25,000) and geodetic data have been sought unsuccessfully since end of World War II. Collection now made a top priority target to fulfill a First Category Priority National Intelligence Objective (para. f); coordinated clandestine effort being markedly increased; yield to date, 13 East German map sheets at 1:25,000; 102 additional sheets obtained through chance events (defections).

b. Efforts made at international scientific meetings to secure data; no success to date.

E. Comparison of US and USSR

1. Competence of US and USSR geodesists -- generally comparable; Soviets possibly superior in field of theoretical gravity and number of trained personnel.

2. USSR has vastly greater number of trained geodesists for future use in missile operations.

3. Soviets have geodetic targeting advantage over US, resulting from:

a. Soviet policy of withholding topographic maps from West since 1946 -- all-purpose Soviet series at 1:100,000 very tightly held; available large-scale maps are of pre-1940 date and limited in coverage, especially for Siberia.

b. Soviet withholding of all gravity and geodetic data since revision of Soviet geodetic system in 1946. Soviets have comparable US data.

ORR/CIA
26 September 1960

ANNEX

BASIC ELEMENTS OF THE GEODETIC PROBLEM

A. Origin of the Problem

1. Geodetic Systems End at Coast Lines

Ground control points on the Earth's surface conventionally are established by measurement from a pre-selected initial point to other points by means of triangulation (distances between points of triangles are calculated through the measurement of angles). Since this procedure is impossible over ocean areas, continental geodetic systems stop at coast lines. Limited ocean spaces can be covered by direct measurement of sides of triangles (trilateration) from continent-to islands-to continent, using electronic techniques. This is called HIRAN. Europe has been tied with North America through Canada with an estimated uncertainty of plus or minus 240 feet. Such ties were made in the Far East and are now being undertaken to interconnect Australia, New Guinea, the Marshalls, and other islands farther east. No HIRAN connection between the Tokyo and North American datums is possible.

B. Sources of Errors

1. Size and Shape of the Earth; Datums

Computing relationships of control points for small areas (property surveys) is easy because computations are made on a plane surface. For large areas where earth curvature is involved, however, computations are made on a curved surface of a near-sphere with predetermined dimensions. Such a figure, the ellipsoid of reference, has definite estimated lengths of the equatorial and polar axes and a ratio between the two that defines the flattening. Because none of these can be measured directly, they have throughout the history of geodesy been differently estimated by geodesists of various countries. The ellipsoid of reference plus the initial point of a geodetic network defines a distinctive datum. Any change or difference in any one of the dimensions of an ellipsoid or in the initial point changes the datum and the resultant geodetic system. The joining of two or more datums creates discrepancies at points common to the datums, as at a border between countries. The US uses the North American Datum, 1927,

based on the Clarke ellipsoid of 1866. The Soviets use the Pulkovo Datum, 1942, based on the Krasovskiy ellipsoid of 1940. The joining of the datums of continents is further complicated by the lack of intervening triangulation over bodies of water (now corrected with HIRAN ties by the USAF), thus giving rise to errors in computing distances and directions between widely separated launch and target points for ICBM operations.

2. Fitting of the Ellipsoid to the Geoid

Because the earth is not a true sphere, and hence not a smoothed surface, mathematical difficulties (and discrepancies) arise in fitting the ellipsoid of reference, a mathematical approximation to the earth, to the geoid, a generalized, undulating representation of the sea-level earth surface. The latter cannot be observed directly but must be deduced from astronomic observations or from the measurement of random variations in the force of gravity from point to point on the earth's surface. Of these, only gravity can be measured on both land and sea; astronomic determinations at sea cannot be measured within better than a 1-mile error. The unknown angular separation between a geoid and an ellipsoid leads to angular errors -- deflection of the vertical -- since the plumb bob of surveying instruments is perpendicular to the geoid and not to the ellipsoid on which all computations are made. For very small countries it has been sufficient to assume that the geoid and ellipsoid were coincident; for others the errors could in some cases be corrected by astronomic methods. But, for a country as broad as the USSR, the errors were found to be inadmissible, amounting to 40-50 times the errors of field work. In the 1930's the Soviets learned that the German ellipsoid then in use (Bessel) and the conventional western method of computation (development method) gave an error of some 900 meters (3,000 feet) in the positions of common points. As a result, a new ellipsoid was computed in 1940, and a new method of computation was adopted (projection method), in which points are projected perpendicular to the ellipsoid. The Soviets now assert that the inferiority of the development method will be felt sharply in the future when adjoining nets are connected and that divergencies will make cartographic unification impossible. Essential to the projection method are gravity data, for which the Soviets began systematic surveys in 1932. The technique of this method is similar to that used by the USAF in positioning Ascension Island to Cape Canaveral, in which an accuracy of plus or minus 500 feet is claimed. The method is being used by the Soviets to establish geodetic positions in Antarctica on the Soviet ellipsoid, a part of the development of a Soviet world geodetic system.

C. US Solutions

1. Two agencies in the US are concerned with the US problem -- the USAF, Aeronautical Chart and Information Center (ACIC) and the US Army Map Service.

25X1X7 [redacted] 25X1X7

2. Army Map Service

The US Army Map Service effort of long standing has been directed to (a) a derivation of a new ellipsoid based on the classical astro-geodetic method, (b) an adjustment of the various European national geodetic systems into a European Datum, and (c) the conversion of the Soviet 1932 system to the European Datum. This program has served an essential, basic purpose but has two weaknesses: (1) limitations are inherent in the astro-geodetic method of deriving an ellipsoid, i.e. it is not earth-centered; and (2) the European Datum work, as a first approximation, was not scientifically rigorous enough, and consequently the International Association of Geodesy is now undertaking another readjustment that will take a number of years to complete.

25X1X7 [redacted] agrees as to the existence of these deficiencies and has a number of reservations concerning the soundness of the conversion of the Soviet 1932 system to the European Datum, including reservations resulting from analyses of Soviet surveys (all pre-1932) that

25X1X7 [redacted] has been re-evaluating point by point (in one instance, a 27 second error was found in one Soviet position, which amounts to a displacement error of 2,700 feet).

3. USAF-ACIC

The USAF has taken the gravimetric approach for the establishment of a world geodetic system, including the derivation of a new ellipsoid, which is earth-centered. The gravity approach is comparable to the Soviet method and is believed to be more satisfactory, provided that the USAF (1) collects sufficient gravity data over the oceans, and (2) obtains Soviet gravity catalogs covering the USSR.

4. Intercontinental Connections

Although a number of important programs are underway, some -- such as MIRAN connections, the IGY lunar-photography program, satellite tracking, and ballistic-flare triangulation -- will provide information

needed for cross-checking intercontinental ties. Others -- such as the world gravity survey -- will provide information that will significantly improve (a) the Defense World Geodetic System and (b) the accuracy of positioning submarine launch points for the Polaris missiles.

5. The Map and Data Gap

The most serious gap in US target-positioning capabilities is the lack of modern Soviet topographic maps and geodetic and gravity catalogs. Without these the US will be seriously handicapped in deriving geodetic positions, especially of ballistic missile sites in areas for which neither topographic map coverage nor geodetic or gravity data is available. Such areas include the vast territory east of the Urals and north of the Trans-Siberian railway. For large portions of this area, it is still doubtful whether such sites could be located to within 1 nautical mile. Even with aerial photography (satellite or other), it is doubtful if most of the sites could be located with an accuracy of 1,000 feet, the minimum error accepted in specifications for USAF weapons systems.

D. Efforts Toward Map and Data Collection

1. Overt collection efforts for large-scale maps of the Sino-Soviet Bloc date back to World War II. There has been no success to date.

2. Growing awareness of the seriousness of this gap has led to elevating the collection requirements to top priority for the fulfillment of a First Category Priority National Intelligence Objective for precise geodetic location of critical targets (para. f).

25X1X4

25X1X4 [redacted] The closest possible coordination is maintained between the CIA and the Army, USAF, and Navy.

b. Some success has been achieved in map collection for East Germany, 13 map sheets at 1:25,000 having been obtained as a direct result of programmed collection and 102 through chance events (88 from an East German border-guard defector). No comparable map sheets have been obtained on the USSR proper or any other Bloc area.

3. US scientists are being informed of existence of known catalogs to stimulate scientific pressure on Soviet Bloc scientists to release gravity data.